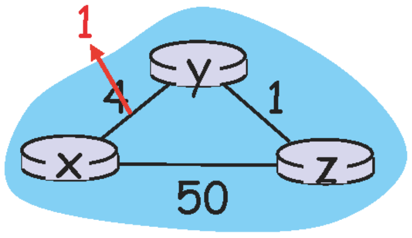
Distance vector: link cost changes

link cost changes:

- node detects local link cost change
- updates routing info, recalculates distance vector
- if DV changes, notify neighbors



"good news travels fast"

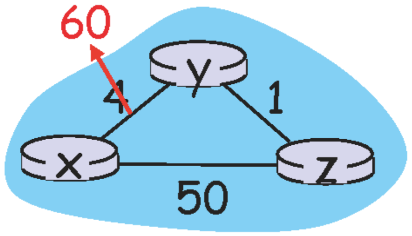
t_0 : *y* detects link-cost change, updates its DV, informs its neighbors.

t_1 : *z* receives update from *y*, updates its table, computes new least cost to *x* , sends its neighbors its DV.

t_2 : *y* receives *z*'s update, updates its distance table. *y*'s least costs do *not* change, so *y* does *not* send a message to *z*.

Distance vector: link cost changes

link cost changes:



- node detects local link cost change
- *bad news travels slow* - "count to infinity" problem!
- 44 iterations before algorithm stabilizes: see text

poisoned reverse:

- If Z routes through Y to get to X :
  - Z tells Y its (Z's) distance to X is infinite (so Y won't route to X via Z)
- will this completely solve count to infinity problem?

Comparison of LS and DV algorithms

message complexity

- ***LS:*** with n nodes, E links, O(nE) msgs sent
- ***DV:*** exchange between neighbors only
  - convergence time varies

speed of convergence

- ***LS:*** $O(n^2)$ algorithm requires O(nE) msgs
  - may have oscillations
- ***DV:*** convergence time varies
  - may be routing loops
  - count-to-infinity problem

robustness: what happens if router malfunctions?

LS:

- node can advertise incorrect *link* cost
- each node computes only its *own* table

DV:

- DV node can advertise incorrect *path* cost
- each node's table used by others
  - error propagate thru network

Chapter 4: outline

4.1 introduction

4.2 virtual circuit and datagram networks

4.3 what's inside a router

4.4 IP: Internet Protocol
- datagram format
- IPv4 addressing
- ICMP
- IPv6

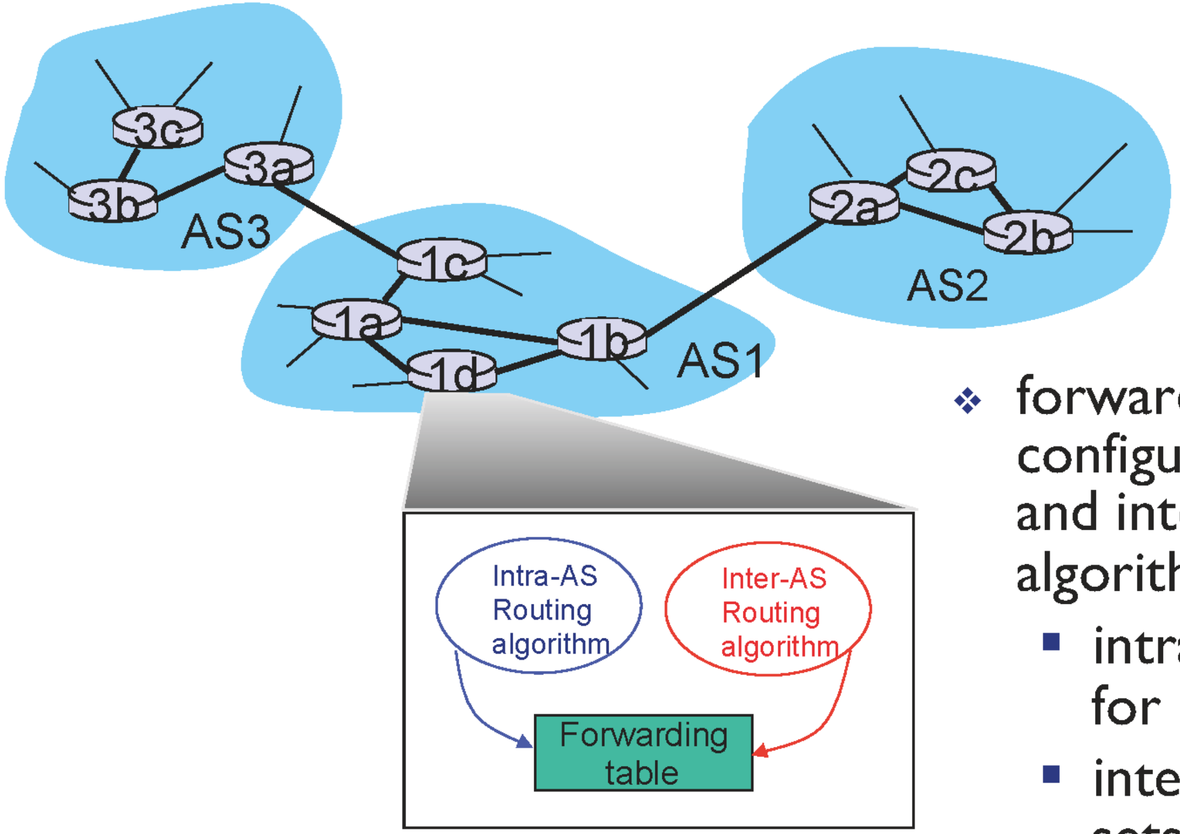
4.5 routing algorithms
- link state
- distance vector
- hierarchical routing

4.6 routing in the Internet
- RIP
- OSPF
- BGP

4.7 broadcast and multicast routing



Interconnected ASes



- forwarding table configured by both intra- and inter-AS routing algorithm
  - intra-AS sets entries for internal dests
  - inter-AS & intra-AS sets entries for external dests

Hierarchical routing

our routing study thus far - idealization

- all routers identical
- network "flat"

… *not* true in practice

scale: with 600 million destinations:

- can't store all dest's in routing tables!
- routing table exchange would swamp links!

administrative autonomy

- internet = network of networks
- each network admin may want to control routing in its own network

Hierarchical routing

- aggregate routers into regions, "autonomous systems" (AS)
- routers in same AS run same routing protocol
  - "intra-AS" routing protocol
  - routers in different AS can run different intra-AS routing protocol

gateway router:

- at "edge" of its own AS
- has link to router in another AS

Chapter 4: outline

PART I

AS: Autonomous Systems

Autonomous Systems (ASes)

An autonomous system is an autonomous routing domain that has been assigned an Autonomous System Number (ASN).

> … the administration of an AS appears to other ASes to have a single coherent interior routing plan and presents a consistent picture of what networks are reachable through it.
>
> RFC 1930: Guidelines for creation, selection, and registration of an Autonomous System

AS Numbers (ASNs)

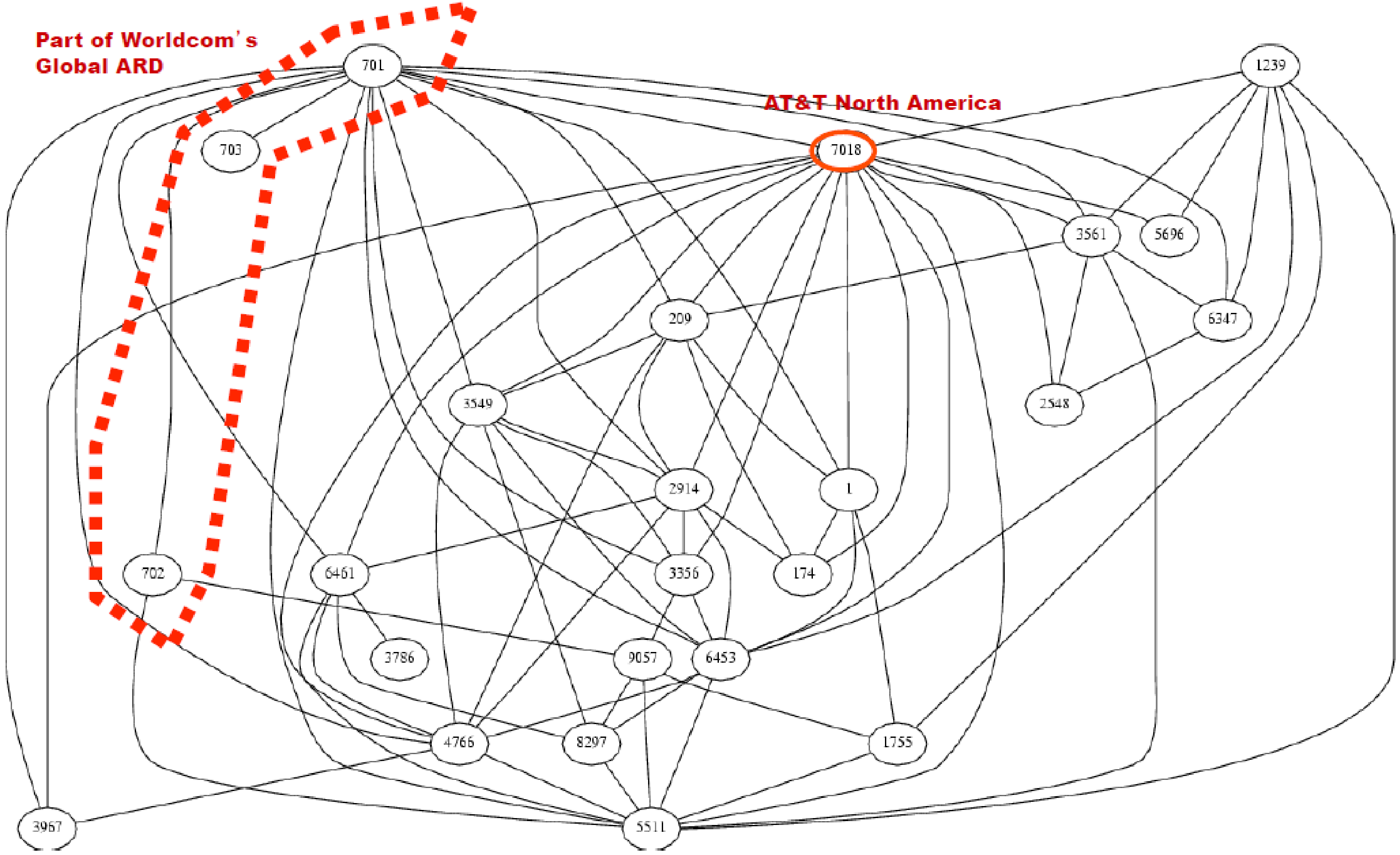
ASNs are 16 bit values.
64512 through 65535 are "private"

Currently over 11,000 in use.

- **Genuity (f.k.a. BBN): 1**
- **MIT: 3**
- **Harvard: 11**
- **UCLA: 52**
- **AT&T: 7018, 6341, 5074, ...**
- **Sprint: 1239, 1240, 6211, 6242, ...**
- **Hanyang Univ: 9322**
- **Idaho Regional Network: 62870**
- **...**

ASNs represent units of routing policy

AS Graphs Can Be Fun



The subgraph showing all ASes that have more than 100 neighbors in full graph of 11,158 nodes. July 6, 2001. Point of view: AT&T route-server

PART II

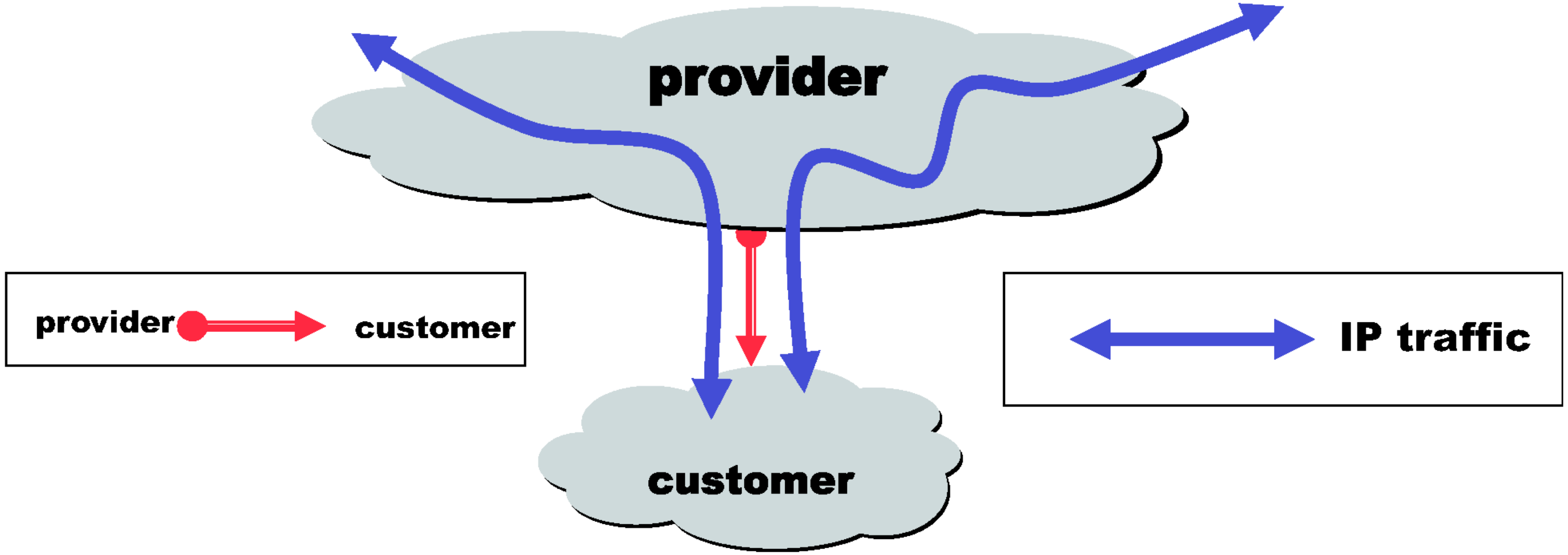
Relationships Between Networks

Some Costs of Running an ISP

- **People**
- **Physical connectivity and bandwidth**
- **Hardware**
- **Data center space and power**
- **…**

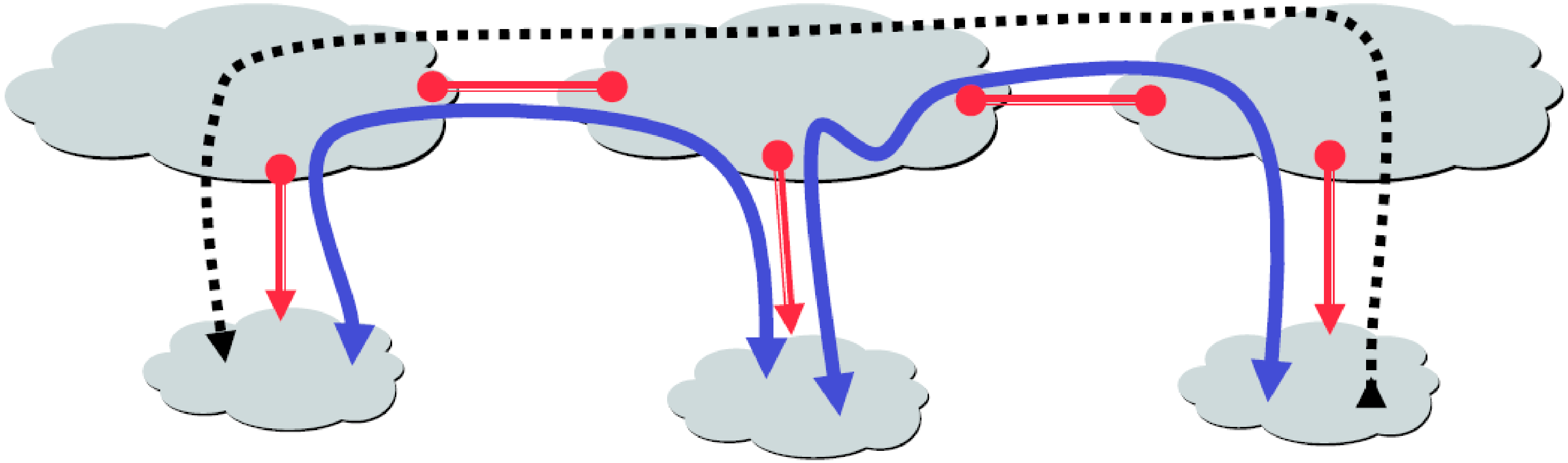
A lot of money…

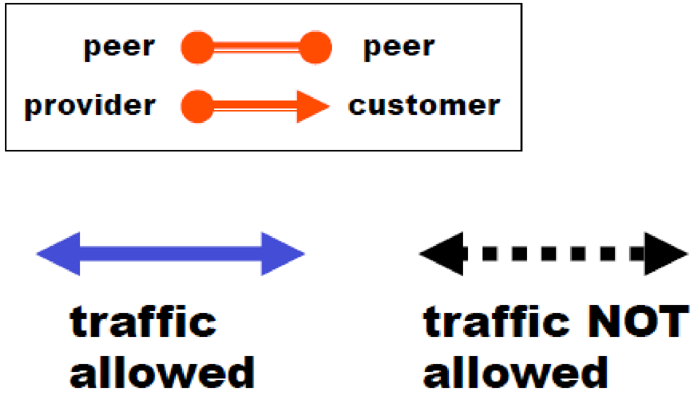
Customers and Providers



Customer pays provider for access to the Internet

The "Peering" Relationship



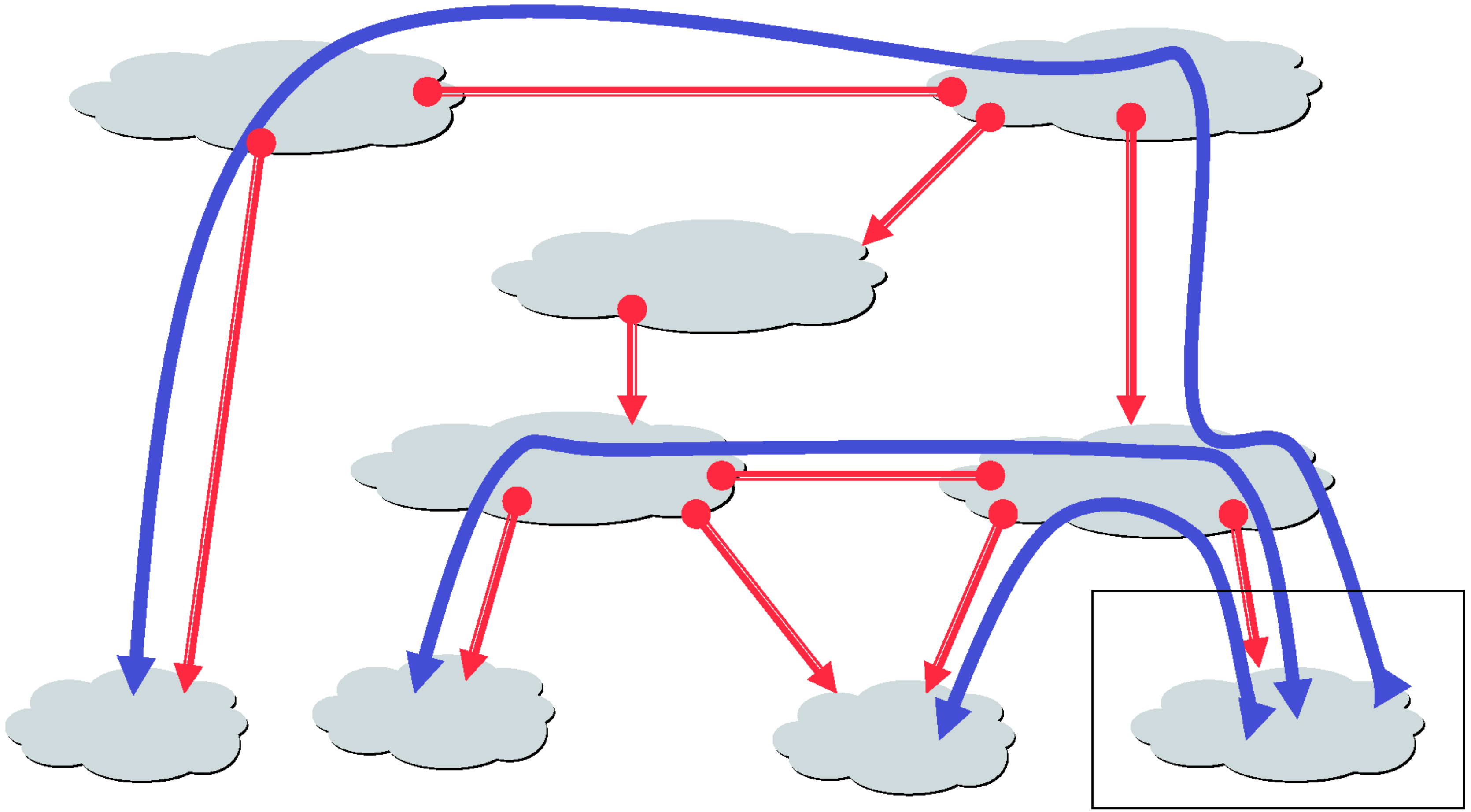


Peers provide transit between their respective customers

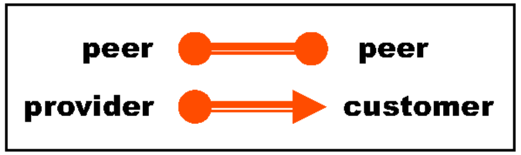
<u>Peers do not provide transit between peers</u>

Peers (often) do not exchange $$$

Peering Provides Shortcuts



Peering also allows connectivity between the customers of "Tier 1" providers.



PART III

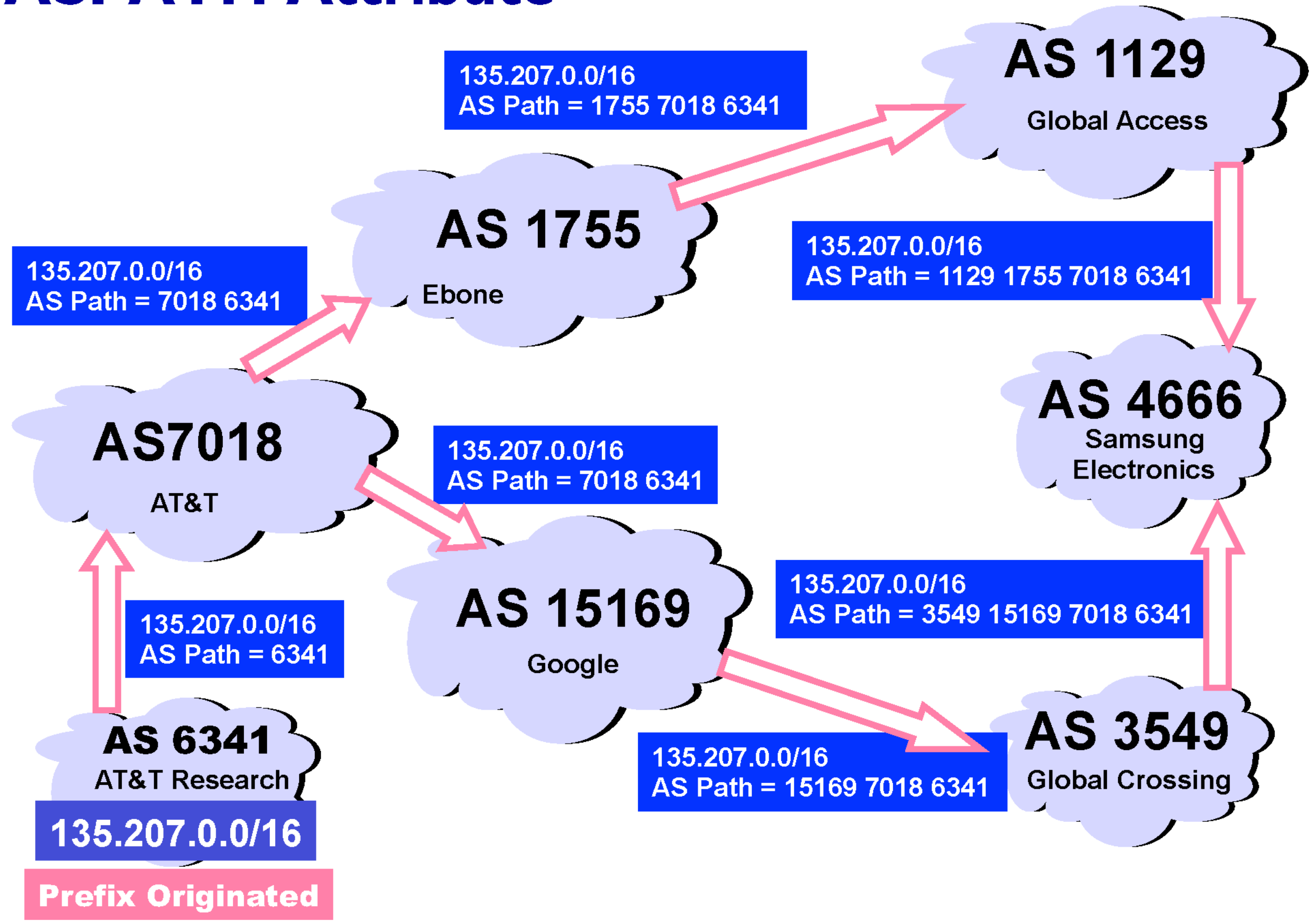
Implementing Inter-Network Relationships with BGP

BGP-4

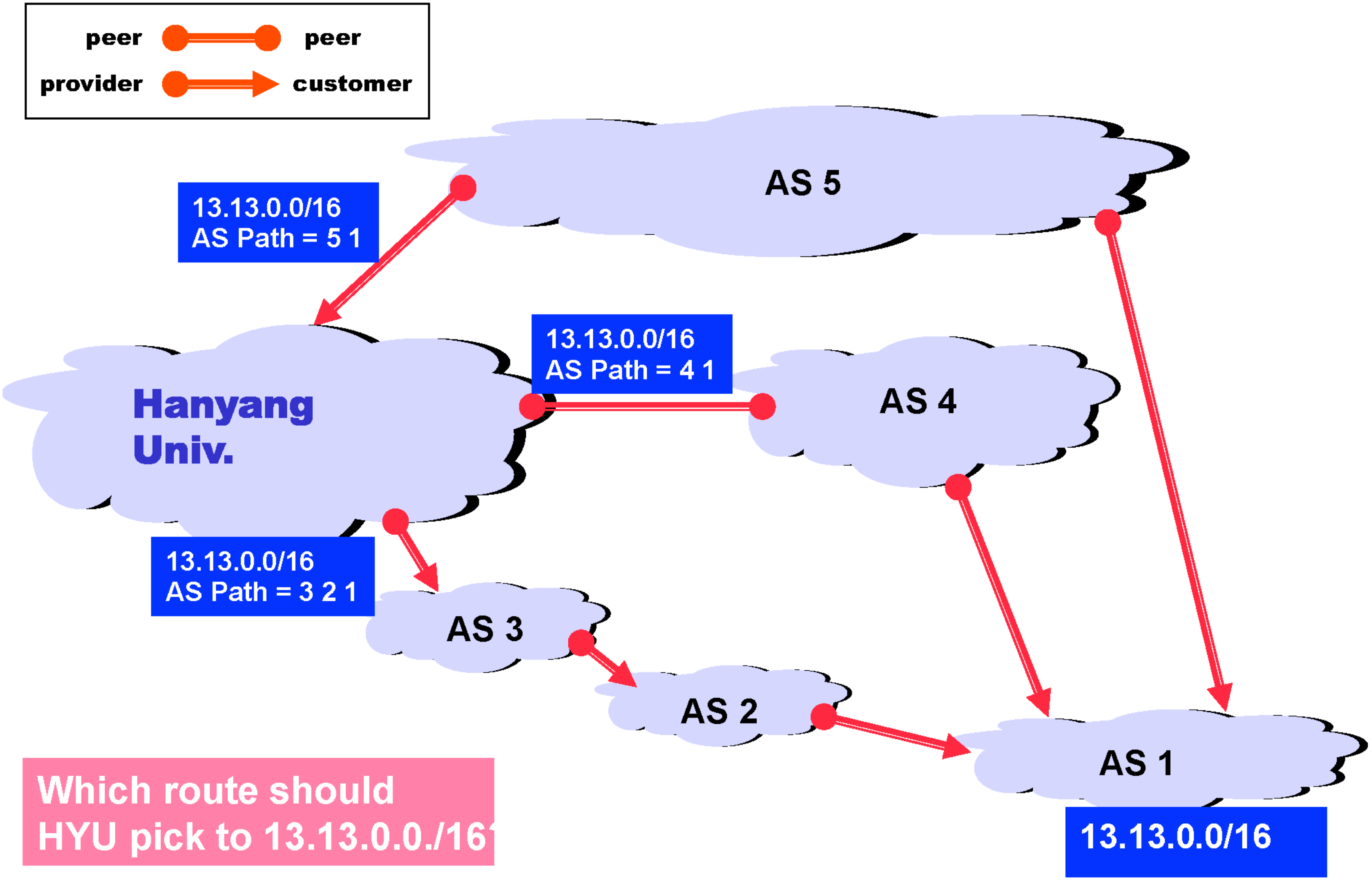
- BGP = <u>B</u>order <u>G</u>ateway <u>P</u>rotocol
- Is a **<u>Policy-Based</u>** routing protocol
- Is the **<u>de facto EGP</u>** of today's global Internet
- Relatively simple protocol, but configuration is complex and the entire world can see, and be impacted by, your mistakes.

- **1989 : BGP-1 [RFC 1105]**
  - **Replacement for EGP (1984, RFC 904)**
- **1990 : BGP-2 [RFC 1163]**
- **1991 : BGP-3 [RFC 1267]**
- **1995 : BGP-4 [RFC 1771]**
  - **Support for Classless Interdomain Routing (CIDR)**

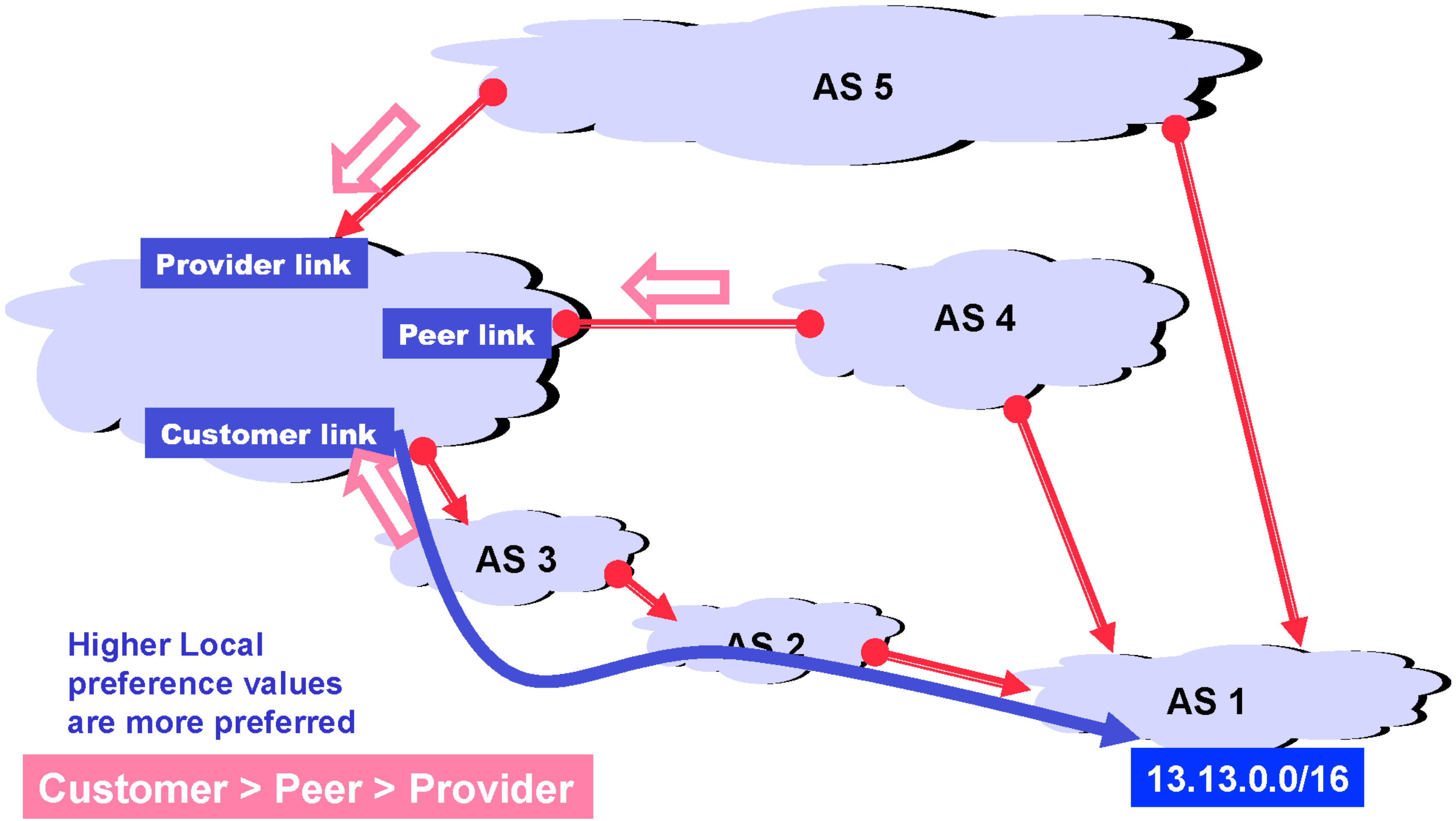
ASPATH Attribute



So Many Choices



LOCAL PREFERENCE!



Higher Local preference values are more preferred

Customer > Peer > Provider